PUTTING RESEARCH TO WORK **BRIEF**

Scanner Takes Air Void Analysis Out From Under Microscope

The durability and performance of portland cement concrete varies with the volume of cement, sand, aggregate and water used in a mixture, as well as its air content. For optimal durability, air must be distributed in properly sized bubbles spaced fairly evenly throughout the mixture, protecting concrete pavement from cycles of freezing and thawing. Upper Midwest state DOTs specify air entrainment volumes in concrete mixes and require verification during construction.

What's the Problem?

Engineers historically added vinsol resins (naturally occurring wood resins) to mixes to create a desirable air-void system. WisDOT uses standard ASTM tests to measure the air content in fresh concrete, but these tests measure only total air content; engineers infer air void size distribution and bubble size from these tests. To determine the true air void size distribution and other parameters, hardened concrete samples are tested according to ASTM C 457, in which a light cast across the surface of a polished slab creates shadows in voids that are counted under an optical microscope.

Recently many agencies have shifted toward non-vinsol air-entraining admixtures, commonly called synthetic air-entraining admixtures. Evidence indicates that these admixtures create an air-void system with a larger portion of small voids. However, fresh concrete tests can be insensitive to small air voids, which may cause artificially low readings in concrete with a large amount of small voids. If mix plant personnel adjust a mix to correct for "low" measured air content, the resulting mix may have too much entrained air, which leads to weak, overly permeable pavement vulnerable to freeze-thaw damage.

To accurately establish air entrainment properties in concrete, engineers need a test of hardened concrete that eliminates operator subjectivity and variability in bubble counts, and that correlates with freeze-thaw tests and fresh concrete tests for various mixtures.

Research Objectives and Methodology

In order to develop less subjective, more repeatable methods for assessing air voids in hardened concrete, this study sought to:

- Identify best practices in construction and materials selection for producing consistent, adequate air-void systems in portland cement concrete pavements, and identify viable new methods for assessing air-void systems in concrete.
- For mixtures prepared with vinsol resin and those prepared with synthetic agents, correlate measurements of air content in fresh concrete with measurements of hardened concrete air-void system parameters determined with ASTM C 457.
- Evaluate emerging technologies for assessing air-void systems in hardened concrete.
- Correlate air-void system parameters measured with all techniques with freeze-thaw testing data gathered via ASTM C 666.

To accomplish these objectives, the researchers first performed a literature review and synthesis. They then prepared representative concrete mixtures, including mixtures containing fly ash. They tested fresh concrete for air content and hardened concrete for freeze-thaw behavior and air-void system characteristics, and analyzed the data for correlations.

Results

Two emerging technologies appear promising for assessing air-void system parameters in hardened concrete. In one, investigators collect high-resolution images of cross sections from concrete cores with a flatbed scanner and use software to identify each image pixel as aggregate, cement paste or air void. In the other, investigators use a CT X-ray scanner to measure a sample's air-void system param-

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"Flatbed scanners offer an accurate and less subjective method for evaluating air systems in hardened concrete."

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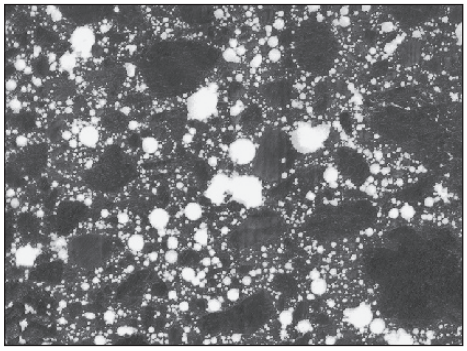

Automated calculation of air voids from a scanned image, right, is accurate and less time-consuming than microscopic evaluation of the same sample, left (Fig. A-1 and A-2 of the final report).

eters in three dimensions, showing the spatial distribution of aggregate, cement paste and air voids. The scanner method is more feasible to implement and more cost-effective than CT X-ray scanning. Specific findings include:

- Fresh concrete tests can underestimate the air content of hardened concrete mixtures prepared with synthetic admixtures, possibly due to the air void size distribution produced by these admixtures. This is most common for mixes with high air contents.
- In general, results from fresh concrete tests correlate well with results from tests of hardened concrete (ASTM C 457) in the 18 examined mixtures.
- Freeze-thaw tests showed that each mixture performed well, except for one mixture that employed a low dose of vinsol resin.
- The flatbed scanner was shown to be a viable device for ASTM C 457 testing.
- CT X-ray scanning is a promising emerging technique for measuring air void characteristics of both fresh and hardened concrete, despite current drawbacks.

Benefits

The flatbed scanner method will allow WisDOT engineers to more effectively monitor the quality of air-void systems in concrete, leading to more durable pavement in Wisconsin's challenging freeze-thaw environment. This repeatable, objective method for comparing hardened concrete air-void systems to those projected by fresh concrete field tests will considerably reduce the labor hours required for testing, thereby reducing costs as well.

Implementation

The results from this research project and a related pooled fund project that WisDOT participates in, TPF-5(014), will be compared with research on air void analyzer technology to determine the best option for WisDOT to use in quality control testing of concrete air-void systems.

Further Research

Investigators recommend that WisDOT consider further research in three areas:

- Reducing air entrainment requirements for concrete mixes. It appears that with current admixtures and procedures, engineers can achieve adequate air void spacing with less air volume without sacrificing durability.
- Refining flatbed scanner methods to address image-processing problems.
- Developing and refining CT X-ray scanning software and computing algorithms to make this technique more viable for use with fresh and hardened concrete.

This brief summarizes Project 0092-03-16, "Evaluation of Methods for Characterizing Air-Void Systems in Wisconsin Paving Concrete," produced through the Wisconsin Highway Research Program for the Wisconsin Department of Transportation Research Program, 4802 Sheboygan Ave., Madison, WI 53707.

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"This research is helping WisDOT develop a better automated test of air systems in hardened concrete that will reduce the amount of expensive, skilled labor we require for laboratory verification testing."

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